

POSSIBLE ORIGIN OF UNEXPECTEDLY HIGH ALKALINITIES IN QUARTZ SANDS OF HIGH DUNES AT WARREN DUNES STATE PARK, MICHIGAN¹

JANE L. FORSYTH AND ERNEST S. HAMILTON

*Departments of Geology and Biology, Bowling Green State University,
Bowling Green, Ohio 43403*

ABSTRACT

Unexpectedly high pH values (generally 7.9), encountered on loose dune sand and sandy soils on the Warren Dunes of southwest Michigan, were identified initially by the presence of certain lime-loving tree species (hackberry, hoptree, red cedar). Earlier workers (Kurz, 1923; Olson, 1958) had recognized this condition, though their published values do not exceed pH 7.65, and had explained it as being due to carbonate grains, originating in till of wave-cut cliffs, being blown with the quartz sand up onto the dunes. Microscopic analysis of dune sand revealed less than two percent carbonates, so this method is not believed to be adequate to produce the high pH values. A better theory is that spray from Lake Michigan (pH 8.2-8.4), blown up onto the dunes by strong west winds, especially during winter storms, evaporates, leaving a precipitate of dissolved carbonate on the sand grains; the precipitate may subsequently be redissolved, moved downward, and reprecipitated by rainwater. Actually both processes probably contribute to the high alkalinities, but, for pH values of 7.9, most of the carbonate is believed to come from the lake's alkaline, wind-transported spray.

Unexpectedly high pH values (mostly 7.9) were obtained from soil and sand samples from the Warren Dunes of southwestern Michigan. These dunes are located on the southeast shores of Lake Michigan two and a half miles north of Sawyer, in NW $\frac{1}{4}$ sec. 25 and NE $\frac{1}{4}$ sec. 26, T. 6 S., R. 20 W., in Lake Township, Berrien County and are some of those made famous by Cowles' work (1899). These data were obtained during field trips to this area with several Bowling Green State University classes in Advanced Terrestrial Ecology in May of 1972 and 1973.

The first hint of such unusually high pH values came when hackberry trees (*Celtis occidentalis* L.), some of considerable size, were encountered along the margin of the wooded area on the east side of the high dunes, and hop-trees (or wafer-ash, *Ptelea trifoliata* L.) were found on and near the dry, loose-sand summits of some of the dunes. In addition, a few red cedar trees (*Juniperus virginiana* L.) were seen, species also reported by Olson (1958). These trees normally occur in areas of limy, high-pH substrate (Braun, 1961; Hamilton and Forsyth, 1972; based also on some of our unpublished observations from the Erie Islands area). Subsequent analysis of topsoil from the eastern slopes of some of the wooded dunes, in connection with a class project, revealed a high pH value and raised a question as to values of pH that might be found elsewhere in the dune area.

Low pH values were expected in these dunes, as the sand is composed dominantly of quartz (based on Olson, 1958, p. 156, and on our systematic microscopic examination—carbonates made up less than 2 percent of the sand). Locally organic debris was also present in the sand; together with the quartz, this debris should have resulted in much more acidic reactions. In similar situations farther north, in Muskegon County, loose high-dune sand has pH values of only 5.0 to 6.5 (Pregitzer, 1968, p. 56-57). In contrast, Kurz (1923, p. 22) reported "alkaline soil sands" with pH values of 6.5 to 6.0 on the loose unstable sand of the high dunes in the Warren area. This he explains by suggesting that the high alkalinities of the Lake Michigan water "accompany the sand washed ashore by the waves," a method not made entirely clear, though he then points out the presence of some

¹Manuscript received July 24, 1972.

plant species that he acknowledges as normally occurring on acid soils (Kurz, 1923, p. 14 and 17). He notes also that "this alkalinity is replaced by acidity as we move landward . . . in the older sands farther from the lake" (p. 14 and 20), variations of which he explained "perhaps in the differences in moisture and organic content, aeration, leaching, etc." (p. 27).

Olson (1958, p. 153) also found high alkalinities on the dunes and an increase in acidity—from a "high initial value" of 7.65 pH, to 6.0 to 6.6 in soils 1,000 years old, to values of 4.4 to 5.6 in soils 8,000 years old. Olson, however, relates this change entirely to the amount of leaching that has gone on. Thus, according to Olson, the changes in pH with increasing distance from the lake shore, a relationship which he does not discuss directly, are presumably, by his interpretation, simply a result of the soils being older, farther from the lake. Close to the lake shore, Olson found no acids in the dune-sand soils, "presumably because carbonates [in the quartz sand] had neutralized them" (p. 162), though he does not explain how quartz sand (p. 156) could contain any significant amounts of carbonates.

In a study of the sands composing the beaches along Lake Michigan, Pettijohn (1931) did identify, in the sand, the presence of some carbonate in the form of grains of limestone and dolomite derived from the local glacial till by wave erosion; he identified also a smaller amount of shell fragments. However, his studies showed that there was less of this carbonate admixture in the beach sands on the eastern shores of Lake Michigan than there was on the western and that amounts of these carbonates decreased southward (along both shores), in the direction of the longshore current. Thus, at the Warren Dunes, which occur far south on the east side of the lake, the proportion of carbonates should be at almost a minimum in the beach—his data show three percent carbonates by weight—and even less in the high dunes (which he did not study). Samples of sand collected along the transect used in our study revealed less than two percent carbonate grains.

Our survey followed an east-west transect located just north of a very large blowout, which lies north of the main swimming beach and just south of the extensive beech-maple forest in the northern half of the park (in NW $\frac{1}{4}$ sec. 25 and NE $\frac{1}{4}$ sec. 26, T. 6. S., R. 20 W.). The transect included considerable areas of open, loose sand, especially at the higher elevations and near the lake; most of the pH measurements were made in this loose sand.

Testing was done with Cornell University soil-pH field-testing kits, which measure pH values of from 7.0 to 8.2. Accurate readings at the upper limit of these testing kits is sometimes difficult, so it is possible that some of the values reported below are not quite correct, probably being somewhat low. This suspicion is supported by our reading of 7.9 for the lake water adjacent to the dunes; lake water which reportedly has a true pH of 8.2–8.4 (according to Dr. Harry V. Leland, personal communication, March 6, 1974).

Values of PH were determined for samples taken in the following areas:

- (1) water in the swampy lake at the east base of the dunes;
- (2) soil, from both the A and B horizons, occurring on a steep wooded north-facing slope on the east side of the dunes; and
- (3) sand, both at the surface and at a depth of 10–15 inches,
 - (a) in loose-sand areas on the higher central dunes 150 feet above the lake,
 - (b) on the western lake-facing side of the high dunes, and
 - (c) on the low foredunes just above the back of the beach.

Sampling was done only across the dune area and did not extend onto the sand plains east of the dunes. Thus it did not extend far enough from the lake to take in the area of lower pH values reported by Kurz (1923) and, indirectly, by Olson (1958).

All of the pH values recorded for the dune sands were extremely high, much higher than those reported by previous workers (Kurz, 1923; Olson, 1958; Pregitzer, 1968). In all cases but those under (2) above, the values were uniformly 7.9.

The exception, the wooded area, had values of 7.7 for the A horizon and 7.8 for the B horizon. Such values, though still highly alkaline, may record the effects of acid organic material in the soil.

Only two explanations for the high alkalinities of the Michigan-shore dunes are given by the earlier authors. According to Pettijohn (1931), some sand-sized fragments of limestone and dolomite were among the materials eroded from a wave-cut cliff in till to the north and moved southward by longshore currents to the beach here, from where this sand, together with some small shell fragments, was blown landward into the high Warren Dunes. Kurz (1923) said simply that the high alkalinities of the lake water "accompany the sand washed ashore by the waves," the exact method explained no more than this. Olson (1958) gives no better explanation than that "the high initial pH value . . . is clearly due to soluble carbonates" (Olson, 1957, p. 162).

Carbonate fragments may be fairly common in the till that forms wave-cut cliffs along the shore, but such fragments are less abundant on these southeast Lake Michigan beaches than elsewhere around the lake (Pettijohn, 1931). In addition, many of these fragments must be lost by solution and abrasion during transport in the lake. Certainly they make up less than two percent of the sand forming the high dunes, sand which is composed of more than 90 percent quartz (based on microscopic examination of samples collected from along the transect). Thus, this interpretation does not seem adequate to explain the very high pH values found in the sand of these dunes.

A much more likely explanation is that spray from the lake (pH 8.2-8.4), blown up onto the dunes by strong west winds, especially during winter storms, would leave carbonate on the sand-grain surfaces as it evaporated. This process, throughout many years, could well introduce considerable amounts of lime into the surface layers of the sand, from where rain water could dissolve and move it downward deeper into the sand. Certainly quartz grains blown up onto the dunes also might well have carried very small amounts of adhering carbonate, but it must take many separate stages of movement for the grains to reach the dune summits, and much of the carbonate load may well be lost en route. Actually, both this process and that of moving the carbonate in spray probably contribute to producing the unusually high alkalinities of the high dunes, but movement in the spray seems to us to be the more efficient of the two methods, and is believed to play the major role in producing the high alkalinities observed on these dunes. The same interpretation may well also explain the abundance, on the quartz sand of Pelee Point, Ontario, Canada, of hackberry and red cedar, both trees found most commonly on alkaline substrates (Braun, 1961; Hamilton and Forsyth, 1972).

ACKNOWLEDGMENTS

Appreciation is expressed to the members of the Bowling Green State University classes in Advanced Terrestrial Ecology, who helped in obtaining the pH determinations, and to Dr. Harry V. Leland, whose constructive criticisms have been so helpful in the preparation of this paper.

REFERENCES CITED

- Braun, E. Lucy. 1961. The woody plants of Ohio. Ohio State Univ. Press. 362 p.
Cowles, Henry C. 1899. The ecological relations of the vegetation on the sand dunes of Lake Michigan. Bot. Gaz. 27: 95-117, 167-202, 281-308, and 261-291.
Hamilton, Ernest S., and Jane L. Forsyth. 1972. Forest communities of South Bass Island. Ohio J. Sci. 72(4): 184-210.
Kurz, Herman. 1923. Hydrogen ion concentration in relation to ecological factors. Bot. Gaz. 7(1): 1-29.
Olson, Jerry S. 1958. Rates of succession and soil changes on southern Lake Michigan sand dunes. Bot. Gaz. 119(3): 125-170.
Pettijohn, F. J. 1931. Petrography of the beach sands of southern Lake Michigan. J. Geol. 39(5): 432-455.
Pregitzer, Karl E. 1968. Soil survey of Muskegon County, Michigan. U. S. Dept. Agric. Soil Cons. Service. 89 p.